1973

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ABSTRACT: Cardiovascular fitness levels were determined for eight urban police officers by maximal treadmill stress testing and pulmonary evaluation. Average age, height, and weight characteristics were 33.1 years, 182.9 cm and 101.6 kg respectively. Measurements of heart rate and blood pressure were obtained for the pre-exercise, exercise, and post-exercise periods. Lactic acid levels were determined at pre-exercise and again at post-exercise. Maximal aerobic power and pulmonary volumes and mechanics were also determined. Average maximal aerobic power and terminal heart rate for the treadmill test were 28.51 ml/kg/min and 186.5 BPM respectively. Four of the police officers were found to be in "very poor" cardiovascular fitness by the Cooper classification. One was in "poor," two were in "fair," one was in the "good" category. None were rated "excellent." Average lactic acid levels were found to be 14.40 mg% at pre-exercise, and 142.0 mg% at ten minutes post-exercise. Pre-exercise blood pressure levels averaged 136.8 mmHg systolic and 85.75 mmHg diastolic. Terminal blood pressure was 187 mmHg and 71.00 mmHg respectively for systolic and diastolic values. Body weight classification indicated the group was 26% overweight. FVC averaged 119% of predicted and FEV (1 sec.) was 86.2% of actual FVC. Pre-exercise sitting systolic blood pressure was found to be 8.4% higher than predicted and the diastolic reading 8.3% above predicted. Results indicated that the police officers had normal pulmonary function, were overweight, moderately hypertensive, and had a "poor" level of cardiovascular fitness. A systematic program of aerobic exercise was recommended.

INTRODUCTION

The records of the Los Angeles County Fire Department's unemployment compensation program for the years 1963 through 1966 revealed that a total of 606 years of experienced manpower were lost as a result of premature retirement due to incapacitating heart disease (Anderson, 1969). A full 75% of the total compensation benefits paid to Los Angeles County firemen during this time period were associated with time lost due to heart attacks and back injuries. The cost in unemployment benefits for heart attacks alone was in excess of $683,000. A medical and physical examination of these firemen revealed a general low level of physical fitness and a high incidence of obesity. Of the 1752 uniformed personnel examined, 31% of the chiefs, 51% of the captains, 44% of the engineers and 38% of the firemen were over the ideal weight recommended in the fire department's training manual. The physical fitness levels of a majority of those evaluated were judged to be low. All individuals were in their middle years with an average age of 33.

Significantly, among the most outstanding, and most easily modified and

controlled coronary heart disease risk factors are obestiy and a lack of habitual physical activity. Investigations by Chiang (1969), Heyden (1971), and Stamler (1971) have demonstrated a strong relationship between excess body weight and elevated blood pressure in the sedentary middle-aged male. The importance of habitual physical activity in the prevention and control of CHD, obesity, and hypertension has been demonstrated in both the Framingham, Massachusetts (Kannel, 1966) and Tecumseh, Michigan (Epstein, 1960) projects and further substantiated in epidemiological studies conducted by Fox (1967), Stamler, (1971), and Morris (1954). Investigations conducted by McDonough (1970), Seigle (1970), Saltin (1969), and Kasser (1969) among others, have revealed that the average middle-aged American male whose occupation involves all but the most strenuous physical labor, has an alarmingly poor level of cardiovascular fitness and cardiac reserve capacity. In fact, of the 106 physically inactive YMCA members evaluated by Doan (1966) 15% showed evidence of myocardial ischemia during maximal exercise stress testing whereas only 13% of the 106 active members demonstrated similar decreases in myocardial perfusion. A systematic program of aerobic exercises and weight control would, therefore, appear to be indicated for most middle-aged American males if they are to forestall debilitating coronary heart disease and maintain sufficient cardiovascular reserve to meet the normal physical demands of an occupation, recreational pursuits and emergency situations.

The Los Angeles County Fire Department recommended a compulsory daily physical fitness program for their firemen in an effort to insure optimal levels of physical performance when carrying out their assigned responsibilities. Ample evidence exists in the literature to support such a program. Redwood (1972), Saltin (1969), Seigle (1970), and Detry (1971), working independently, have trained middle-aged sedentary normal subjects and cardiac patients for time periods varying from 6 to 28 weeks and all have reported significant improvement of cardiovascular function in their subjects at the conclusion of the exercise program. McDonough (1970) in evaluating the physical fitness status of middle-aged males has postulated that the enhanced effect of a systematic physical activity program is equivalent to approximately ten years of the decremental age effect on maximal aerobic power. Current research therefore appears to indicate that systematic programs of physical activity, if adhered to on a regular basis, will enhance cardiovascular fitness, reduce systolic hypertension, and will provide a reasonable control over obesity. (Bloom, 1968; Hanson, 1970; and Boyer, 1970).

The Los Angeles study (Anderson, 1969) further noted that while automation has reduced the physical labor associated with many industries, both firemen and police officers are still subject to emergencies demanding

tremendous physical strength and endurance. The energy demands of a police officer during a normal day's work may average 2-5 kcal/min or 1200 kcal/8 hour shift; a level of energy production roughly equivalent to that encountered in light industry. (Astrand, 1960, p. 441). While this is a comparatively moderate level of work, it is not unusual for an officer to extend himself to maximum capacity several times over a normal working shift. During such crisis situations high levels of cardiovascular fitness and muscular strength are essential to the successful completion of the policeman's assigned duties. Surprisingly, an investigation of the maximal oxygen consumption levels of American policemen revealed that the average 33 year old officer had a maximal aerobic capacity of 2.400 1/min (Astrand, 1969, p. 306). When classified according to the Cooper *Aerobics* system, (1970, p. 28) these officers were found to be in "Poor" (30 ml/kg/min at a body weight of 80 kg) cardiovascular fitness and as such their ability to respond effectively to an emergency situation was questioned. It was concluded that a lack of the elements of a good state of physical fitness would be detrimental not only to the proper completion of a police officer's assigned duties, but also to the police officer personally.

The purpose of this study was to sample a cross-section of the various job responsibilities in an urban police force in order to ascertain whether these police officers demonstrated the same lack of physical fitness that appears to be characteristic of other municipal employees engaged in similarly hazardous occupations.

METHODOLOGY

Eight police officers from an urban midwestern community of approximately 150,000 inhabitants volunteered to participate in this investigation. The average age, height and weight characteristics of the policemen were 33.1 years, 182.9 cm and 101.6 kilograms respectively. (Table 1). Occupational responsibilities were classified according to five categories. Two policemen were classed as foot patrolmen, one was assigned to a patrol car, two were desk clerks, two were administrators, and one a detective (Table 1). Cardiovascular fitness levels were assessed for the eight police officers by maximal treadmill stress testing and pulmonary function evaluation. Determinations of maximal aerobic power were made using a Bruce multistage treadmill test which employed a subject determined end point (Bruce, 1965). Oxygen consumption was measured by an open curcuit sampling procedure utilizing a Technology Versatronics Oxygen Consumption Computer (OCC). Expired gas was directed to the OCC via a high velocity Collins Triple "J" respiratory valve. Oxygen consumption levels were recorded in liters/minute (STPD) and later adjusted for body weight (ml/kg/min). Determinations of oxygen consumption were accomplished

TABLE 1: SUBJECT CHARACTERISTICS

	AGE (yr.)	HEIGHT (in.)	HEIGHT (cm.)	WEIGHT (lb.)	WEIGHT (kg.)
Mean	33.10	72.00	182.90	223.00	101.60
S. D.	7.24	1.64	4.17	43.72	19.73
N.	8	8	8	8	8

JOB CLASSIFICATION

	Foot Patrolman	Patrol Car	Desk/ Clerk	Administration	Detective
N.	2	1	2	2	1

every minute of exercise beginning when the subject's heart rate was 45 BPM below his age adjusted predicted maximum level and ending with his voluntary termination of performance. Heart rate and electrocardiographic responses were monitored telemetrically and recorded for the last 15 seconds of each minute during the pre-exercise, exercise, and recovery periods. A three channel Signatron Bio-Sentry transmitter and a Signatron Model 4200 telemetry receiver were used for all ECG recordings. Blood pressure readings were taken by auscultation using a rack mounted sphygmomanometer. Determinations were made during pre-exercise, every third minute of exercise and for the first three minutes of a ten minute recovery period. To avoid post-exercise syncope resulting from vascular pooling all subjects walked at 2.0 mph, 0 percent grade during the initial three minutes of the post-exercise period. Pre-exercise and ten minute post-exercise blood lactic acid levels were determined by a Sigma Corporation method. (Sigma Bulletin, 1968).

Vital capacity, forced expiratory volume (1 sec.) and maximum voluntary ventilation were measured using a Collins Modular Lung anaylzer according to the methods of Meneely (1957). Pulmonary function determinations were corrected to standard body conditions (BTPS) and expressed as percentages of predicted normal values. Body weight and blood pressure classifications were derived from the Society of Actuaries Body Build and Blood Pressure tables. (Geigy, 1970, p. 553 & p. 711). Results were statistically treated for measures of central tendency (mean) and dispersion (Standard deviation). Statistical analysis of the data was accomplished on an IBM 360 Computer Terminal.

RESULTS

The average maximal oxygen consumption level determined for the eight police officers during treadmill stress testing is shown in Table 2. Maximal aerobic capacity for the group was found to be 2.823 1/min, with the average maximal aerobic power of the officers calculated at 28.51 ml/kg/min. Table 2 also shows the mean performance time, distance traveled and exercise stage completed during the treadmill performance. The mean performance time for the group was 598.5 seconds during which time they traveled 2,600.3 feet. As a group the officers completed 3 and 1/3 of the seven exercise stages before voluntarily terminating the performance due to exhaustion.

TABLE 2

MAXIMAL AEROBIC CAPACITY & POWER

	Oxygen Consumption Liters/Min.	Oxygen Consumption Mg/kg/min.
Mean	2.823	28.51
S. D.	.820	8.43
N.	8	8

TREADMILL EXERCISE DURATION

	Exercise Stage	Seconds	Total Distance (ft.)
Mean	3.33	598.50	2600.31
S. D.	0.62	110.67	722.07
N.	8	8	8

Table 3 shows the cardiovascular fitness classification system of Cooper (1970, p. 28). When classified according to aerobic power, four of the police officers were found to be in "very poor" cardiovascular fitness. One officer was classified "poor," two were "fair," and one was placed in the "good" category. None were rated "excellent."

The hemodynamic responses of the subjects at rest, during exercise and following a post-exercise recovery period are shown in Table 4. Pre-exercise heart rate levels averaged 86.13 BPM while terminal exercise heart rates, obtained for the last minute of the treadmill performance, averaged 186.5 BPM. A decrease in heart rate to 108.6 BPM was observed following a ten minute recovery period. Resting systolic and diastolic blood pressure levels, taken in a sitting position, were 136.8 and 85.75 mmHg respectively. Blood

pressure determinations obtained at the termination of exercise averaged 187 and 71 mmHg respectively for the systolic and diastolic values. Table 4 also contains the average pre- and post-exercise blood lactic acid levels for the subjects. It should be noted that for technical reasons lactic acid determinations were made for only five of the eight officers. The sitting, pre-exercise level for the five subjects was found to be 14.40 mg%, while the ten minute post-exercise value remained inordinately high at 142 mg%.

TABLE 3. CARDIOVASCULAR FITNESS CLASSIFICATION

CATEGORY	N
I. Very Poor	4
II. Poor	1
III. Fair	2
IV. Good	1
V. Excellent	0

Classification based on maximal aerobic power according to *The New Aerobics*, by K. H. Cooper.

TABLE 4

HEMODYNAMIC RESPONSES TO MAXIMAL EXERCISE

Stress Testing

	Heart Rate (BPM)			Blood Pressure (mmHg)	
	Pre-Exercise	Terminal	10 Min. Post-Exercise	Pre-Exercise	Terminal
Mean	86.13	186.50	108.57	136.8/85/75	187.0/71.00
S. D.	15.02	11.74	9.34	7.99/10.10	19.75/11.88
N.	8	8	8	8	8

Pre- and Post-Exercise Lactic Acid Levels

	Pre-Exercise (mg%)	10 Min. Post-Exercise (mg%)
Mean	14.40	142.00
S. D.	8.85	25.64
N.	5	5

An age adjusted blood pressure classification index, based on resting systolic and diastolic pressures is presented in Table 5. The function of this index was to compare the resting blood pressure levels of the eight police officers employed in this investigation with standard values listed by the Society of Actuaries. The predicted normal systolic blood pressure for 33 year old males was 126.5 mmHg. Normal diastolic pressure was listed at 79.3 mmHg. On the basis of these standard values, the subject group was found to be 8.4% and 8.3% higher than normal for the systolic and diastolic measures respectively, and hence was judged to be moderately hypertensive.

TABLE 5

BLOOD PRESSURE CLASSIFICATION

Systolic Blood Pressure (mmHg)

	Actual	**Predicted**	**Percent of Predicted (%)**
Mean	136.80	126.50	108.40
S. D.	7.99	2.00	7.15
N.	8	8	8

Diastolic Blood Pressure (mmHg)

	Actual	**Predicted**	**Percent of Predicted (%)**
Mean	85.75	79.30	108.30
S. D.	10.10	1.67	12.57
N.	8	8	8

Body Weight Classification

	Actual (lb.)	**Predicted (lb.)**	**Percent of Predicted (%)**
Mean	223.00	177.30	126.00
S. D.	43.72	6.94	24.92
N.	8	8	8

A similar procedure was used to classify body weight. Table 5 contains a body weight classification index adjusted for age and height. The predicted average weight for males of comparable age to the police sample was 177.3 lb. The actual mean body weight of the eight officers was 223 lbs.; an over weight index of 26%.

Table 6 shows the actual and predicted values of selected pulmonary function measures obtained on five of the eight officers. The predicted forced vital capacity (FVC) based on age, sex, and body surface area was 4.40 liters. The average FVC volume for the five officers was 5.26 liters, representing an elevation in lung volume of 19% above normal. The mean one second forced expiratory volume (FEV 1 sec.) of the officers was found to be 4.54 liters, with the predicted FEV_1 being 3.5 liters, thus indicating an increase in lung mechanics of 29.6% above average. The FEV_1 sec. was also calculated to be 86.4% of the 5.26 liter actual FEV (Table 6.)

TABLE 6

PULMONARY FUNCTION

Forced Vital Capacity (1/Min.)

	Actual	**Predicted**	**Percent of Predicted (%)**
Mean	5.26	4.40	119.00
S. D.	.50	.14	8.89
N.	5	5	5

Forced Expiratory Volume
One Sec. (Liters)

	Actual	**Predicted**	**Percent of Predicted (%)**
Mean	4.54	3.50	129.60
S. D.	.59	.14	6.50
N.	5	5	5

Percent of Actual Forced Expiratory Volume
One Sec. (Liters)

	FEV	**$FEV_{1\ sec.}$**	**% FEV**
Mean	5.26	4.54	86.40
S. D.	.50	.59	6.50
N.	5	5	5

DISCUSSION

The maximal aerobic power (28.52 ml/kg/min) of the eight police officers used in this investigation was below the average level predicted for American males of similar age and occupational background. While the cardiovascular fitness level of the group was ranked in the second or "Poor" category (25.0-30.1 ml/kg/min) on the Cooper *Aerobics* scale (1970, p. 28), the officers would be placed in the first or "Low" category ($\leqq$ 34 ml/kg/min) when using the Swedish standards of Astrand, (1970, p. 619-622). Similarly, the average aerobic power of 40.5 ml/kg/min for middle-aged males reported by McDonough (1970) is markedly higher than the values observed in this study. Mann (1969) and Ribisl (1969) have also reported significantly higher levels of aerobic fitness in middle-aged males, with their findings ranging from 34-49 ml/kg/min. Other investigators, however, have observed oxygen consumption levels in middle-aged men that compare favorably with the sample of police officers. Drake, (1969) reported that the maximal aerobic capacity of Canadian working men, averaging 33 years of age, was 2.800 l/min and Saltin (1969) in evaluating sedentary males in the same age group, recorded a mean aerobic capacity of 2,890 l/min. Interestingly, in a study conducted by Siegel (1970) using middle-aged males who had been blind for ten or more years, the average maximal aerobic power for the group was 24.0 ml/kg/min. These men had been sedentary due to sight limitations for at least ten years and were still found to have a maximal aerobic power that was only 4 ml/kg/min below the level recorded for the police subjects. While not statistically valid, this comparison between a handicapped group of middle-aged men and the age matched police sample does point to an alarmingly low level of cardiovascular fitness for individuals involved in potentially strenuous work.

Elapsed treadmill performance time has also been used as a means of evaluating cardiovascular endurance capacity (Kasser, 1969; McDonough, 1970; and Doan, 1966). The average treadmill performance time for sedentary middle-aged males on the Bruce Multistage test has been found to be 513 seconds (McDonough, 1970). Total exercise time for the police sample on the same multistage test was 598.5 seconds indicating that the officers performed slightly longer than predicted. Treadmill performance times reported by Kasser (1969) on 117 normal, but sedentary, middle-aged males also compared favorably with the total exercise time recorded in this study. Evidence that the police officers extended themselves to maximum levels of exertion was obtained from nominative data based on an average maximal aerobic power for a given elapsed treadmill performance time. These norms were compiled by McDonough (1970) as a method of validating maximal exercise responses obtained for the Bruce multistage test. By these

standards a ten minute treadmill performance to exhaustion was expected to illicit an age adjusted maximal aerobic power level of 32 ml/kg/min. The police values, although somewhat lower, were considered reasonably close to this level.

It can be concluded from the above comparisons that although the police officers were substandard in cardiovascular fitness, their treadmill exercise duration was equivalent to a level common to most sedentary middle-aged men. In fact, Doan (1966) reports that 21% of all middle-aged men tested terminated performance before attaining stage IV of the Bruce Multistage test.

The average terminal exercise heart rate of 186.5 BPM observed for the police sample was in agreement with the predicted age adjusted maximal heart rates suggested by the Tennessee Heart Association (1970) and indicated that the officers had exercised to maximum capacity. McDonough (1970) and Bruce (1963) have also reported maximal heart rates in middle-aged untrained individuals similar to those observed in this investigation. Doan (1966) further substantiates these findings by indicating that middle-aged sedentary males typically achieve a heart rate of 186 BPM at the beginning of Stage IV in the Bruce test. The above terminal exercise heart rate would then appear reasonable in light of the fact that the police sample voluntarily terminated exercise during the first minute of Stage IV on this test. However, slightly higher maximal heart rates have been observed in the same age group by Saltin (1969) and Kasser (1969).

In an effort to evaluate the percentage of the heart rate range available after cardiac adaptation to Stage I, a heart rate reserve index was calculated. Theoretically, the higher the level of cardiovascular fitness, the lower the cardiac cost of a given sub-maximal work load and therefore, the greater the capacity of the individual to adapt to exercise stress. Formula 1 provides a method of relating the sub-maximal heart rate for Stage I of the Bruce test to both resting and maximal exercise heart rates.

$$(1) \qquad \text{Heart Rate Reserve Index} = \left(\frac{\text{Max. H. R.} - \text{Stage I H. R.}}{\text{Max. H. R.} - \text{Resting H. R.}}\right) \times 100$$

(Kasser, 1969)

The heart rate reserve index of the police sample was 58.38% as compared with an index of 64% reported by Kasser (1969) for 117 middle-aged sedentary males. The index indicated that the police group adapted to exercise stress by increasing cardiac rate and not stroke volume, a response typical of an untrained cardiovascular system.

The average resting systolic and diastolic blood pressures of the police sample were found to be approximately 8% above normal values and

according to the Insurance Underwriters tables printed by the Society of Actuaries (Geigy, 1970, p. 553) the group was slightly hypertensive. Wong (1969) reports that elevated blood pressure, in the absence of other cardiovascular diseases, does not impair exercise performance. Hypertension by itself could therefore not be considered the reason for the poor level of cardiovascular fitness observed in the sample. Cassel (1971), Doan (1966) and Boyer (1970) have all reported resting systolic and diastolic blood pressures in middle-aged men that are similar or greater to the levels observed in this study. Further, the terminal exercise blood pressures determined for the police sample were in agreement with values reported by Kasser (1969), McDonough (1970), and Doan (1966) when stress testing middle-aged sedentary males. Significantly, all three investigators observed a drop in diastolic blood pressure at the maximal exercise intensity. A similar occurance was observed in this study, and was taken as an early indication of a failure of the circulatory system to adapt to maximal exercise stress.

Although immediate post-exercise lactic acid determinations were not made, a comparison with the findings of other investigations was undertaken to demonstrate the slow anaerboic recovery of the police subjects. Saltin (1969), Seigle (1970), and McDonough (1970) have reported lactic acid levels at the termination of maximal exercise in excess of 100 mg%. The police officer's blood lactic acid levels remained in excess of 142 mg% even after ten minutes of post exercise recovery.

Body weight of the sample was classified as 26% overweight. Such excess body weight obviously contributed to the poor level of maximal aerobic power of the sample. Quite reasonably the elevated blood pressure levels discussed above might in part be attributable to this excess body weight.

CONCLUSIONS AND RECOMMENDATIONS

The results of this investigation cannot be construed as a reflection of the entire police department from which the experimental sample was drawn, however, the data obtained did appear to warrant the following conclusions. The police officers had a normal pulmonary funciton, were moderately hypertensive, significantly overweight, and had an overall "Poor" level of cardiovascular fitness. The effectiveness of the police officers in carrying out assigned tasks that placed excessive demands on their aerobic energy system was, therefore, questioned.

While a police officer is not routinely required to engage in heavy physical effort for prolonged periods of time quite frequently he is confronted with crises situations to which he must respond immediately and vigorously. In order that he might effectively cope with the sudden sympathetic storms that attend such physically demanding crisis situations it

is essential that a police officer maintain at least a moderate level of cardiovascular stamina at all times. Therefore the following recommendations were made:

1. A systematic program of physical exercise designed to enhance cardiovascular endurance, muscular endurance and muscular strength should be made available to all police personnel.
2. An officially recognized sports program should be initiated, the purpose of which would be to encourage physical fitness through games and athletics.
3. Periodic information on dietary moderation should be made available to the policemen and their families and
4. An annual age-adjusted physical performance test should be administered to aid the officers in judging their present level of physical fitness.[1]

[1]Modified from Los Angeles Fire Department recommendations (Anderson, 1969).

ACKNOWLEDGMENTS

We wish to thank Nicholas Martinez for his aid in data collection for this investigation.

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